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ABSTRACT

This study was designed to determine (1) if teacher use of specified teaching behaviors leads to the identification of differences in the learning outcomes of pupils in group and independent learning situations; and (2) if knowledge of teacher use of specified teaching behaviors relates to the prediction of variance in pupil post-unit scores. The teacher behaviors that were considered emphasized three instructional functions: (a) causing learner awareness of learning goals; (b) evoking learning performance including completion of the learning task and provision of motivation for learning; (c) assessing learning outcomes. The experiment involved teachers who received special training in the use of seven teacher behaviors and teachers who received no training. Two main implications of this study were found. (1) When the learning environment is controlled in terms of subject matter content and materials, and proportion of time devoted to independent vs. group learning, the group learning situation produces superior outcomes. (2) Measurement of a specific set of teacher behaviors that define only a limited segment of the total teaching act does aid in the prediction of variance in pupil learning outcomes. (FL)

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INDEPENDENT MATHEMATICS LEARNING AS A FUNCTION OF TEACHER BEHAVIORS

by

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INDEPENDENT MATHEMATICS LEARNING AS A FUNCTION OF TEACHER BEHAVIORS*

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During the decade of the 1960's several new patterns of organization for instruction were introduced in the schools. Among these patterns, individualization of instruction received particular attention.

Programs focusing upon individualized instruction introduce at least three important variables to the school setting. These are: altered curriculum content, need for use of a unique set of teacher behaviors, and changes in the proportion of time spent in independent learning.

Of the three, measurement of teacher use of behaviors which support independent learning has received particularly limited attention in research investigations related to individualized instruction (i.e., Mauer, Childs, Ecker, 1969). The present study was conducted in an effort to answer the questions:

1. Does teacher use of a specified set of teaching behaviors lead to the identification of differences in the learning outcomes of pupils in group and independent learning situations?

2. Does knowledge of teacher use of a specified set of teaching behaviors relate to the prediction of variance in pupil post-unit scores?

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Teacher Behaviors

The teacher behaviors that were investigated emphasize three major instructional functions (Gagne, 1967; Bloom, 1968). These are: (a) causing learner awareness of learning goals;(b) evoking learning performance including completion of the learning task and provision of motivation for learning; and (c) assessing learning outcomes. The behaviors are:

1. Specify what is to be learned. This behavior occurs whenever the specific skill or knowledge to be mastered by the pupil is stated and is made known to the pupil.

2. Specify how what is learned will be demonstrated. This behavior occurs whenever a criterion of performance (a standard by which pupil behavior is to be evaluated) or a finished product (a display, report, or other visible evidence of mastery of knowledge or skills) is established.

3. Identify resources to be used by the pupil. Direction of the pupil to the use of such items as textbooks, workbooks, library books, audio-visual materials, programmed instruction materials, manipulative devices, and experimental kits constitutes the use of this behavior.

4. Specify the learning steps to be completed by the pupil. A learning step is specified whenever a task is named that a pupil must complete in order to master a particular skill and/or knowledge.

5. Establish learning checkpoints. A checkpoint is established whenever some type of provision is made for the pupil to receive information (feedback) about the accuracy of his performance.

6. Establish deadlines. This behavior occurs whenever the pupil is committed to a date for the achievement of one or more of the products or criteria of performance that are to be used as measures of the required learning.

7. Describe the next activity the pupil can anticipate doing. Whenever a teacher and pupil agree upon a pupil-selected activity that is not directly related to the demonstrated achievement of what is to be learned, but is an activity in which the pupil may engage upon the accomplishment of some pre-determined goal, an anticipated activity has been described.

Hypotheses to Be Tested

The study was designed to test two null hypotheses:

1. There will be no difference in the performance of pupils in the independent and group learning treatments.

2. Teacher use of the seven behaviors will have no relation to the prediction of variance in pupil post-unit scores.

The definitions used to identify the treatments were:

Independent learning - the learning that occurs when a pupil works without direct teacher supervision. The learning task, or tasks, that are carried out by the pupil have been planned and discussed during any individual teacher-pupil conference. The completion of the tasks is self-paced by the pupil.

Group learning - the learning that occurs when a pupil works with a group of pupils under the direct supervision of the teacher. The learning task, or tasks, in which the pupil engages include teacher demonstrations and group discussions or activities assigned by the teacher to the group as a whole.

Methods

The study involved 34 teachers, 18 who received special training* in the use of the seven teacher behaviors and 16 who received no training. All teachers were volunteers. Of the trained and untrained teachers, 10 trained and 9 untrained were selected at random from each group and assigned to teach an instructional unit on mathematics measurement using independent learning procedures. The remaining 15 teachers (8 trained and 7 untrained) taught the same unit using group learning procedures.

After eliminating the data for pupils who did not take all the tests included in the study, a sample population of 314 pupils was obtained. All pupils received identical instructional units. In the group learning treatment, the entire class membership participated in

*A teacher training course developed by the Far West Laboratory, Minicourse 15: Independent Learning in the Upper Elementary Years, was used for the training program.

the conduct of the unit. The 10 or so pupils included in the study from these classes were selected at random from the total number of pupils participating in the unit. In the independent learning treatment, only the 10 or so pupils randomly selected for participation engaged in the unit activities.

The total group of pupils participating in the study represented a wide range of socio-economic settings. However, the major portion of the pupils came from middle level socio-economic backgrounds.

Three major research activities were completed: (1) measurement of teacher use of the specified teaching behaviors; (2) conduct of a unit on mathematics measurement and assessment of pupil learning outcomes in the four treatment groups -- independent/trained teachers, independent/untrained teachers, group/trained teachers, group/untrained teachers; and (3) investigation of the relationship between teacher use of the specified behaviors and prediction of variance in pupil performance.

The mathematics unit taught by the 34 teachers focused on the topic of measurement. Three reasons contributed to the selection of this topic. First, as demonstrated in a study by Scott (1967), measurement receives limited attention in elementary mathematics textbooks. Thus, it had a high potential for being an area in which pupils would not have previously mastered all the relevant skills. (The pretest data supported this assumption.) Second, measurement skills are an important facet of applied mathematics (Goals for School Mathematics, 1963). Third, measurement skills lend themselves to both independent learning and total group instruction situations and to use with pupils in multiple grades or classes.

The major learning objectives included in the unit were:

1. To learn what characteristics of an object can be measured.
2. To learn the need for likeness between what is to be measured and the unit of measure.
3. To use measurement to determine equivalence of forms.
4. To apply the transitive rule in describing relationships among measures of three or more objects.
5. To relate self-developed measurement units to English standard units of measure and to metric units.

As stated above, during the conduct of the unit 19 teachers utilized an independent training approach to instruction. Within this framework, the teacher worked individually with each of the 10 pupils selected at random from the class membership. At individual meetings, the teacher and pupil outlined cooperatively a plan of study for one or more of the unit objectives. Each pupil then carried out his learning activities independent of work with the other pupils and, for the most part, independent of help from the teacher.

Fifteen teachers conducted the unit employing a group instruction technique. In these classes, planning sessions, assignments, and discussions involved the entire class. Pupils completed the learning tasks at approximately the same time and on the same schedule.

To control for variance in interpretation of treatment conditions, each teacher was asked to keep a record of the total number of minutes devoted to unit activities each day of the experimental period. The teachers also recorded the percent of time each day in which pupils engaged in independent or group learning activities according to the definitions listed earlier in this paper. Table I reports the average amount of learning time in total minutes for each treatment.

TABLE I

Mean Number of Minutes
Devoted to Unit Activities

Independent Trained	Independent Untrained	Group Trained	Group Untrained
523	395	608	527
$\bar{X}$ Independent = 459		$\bar{X}$ Group - 568	

It should be noted that the group treatment on the average had two more hours of learning time than the independent treatment.

Table II lists the mean percent of time devoted to independent and group learning as reported by the teachers.

TABLE II

Mean Percent of Time Devoted to
Independent and Group Learning

Treatment	Percent Independent Learning	Percent Group Learning	Total
Independent Trained	.83	.17	1.00
Independent Untrained	.82	.18	1.00
TOTAL INDEPENDENT	.83	.17	1.00
Group Trained	.40	.60	1.00
Group Untrained	.41	.59	1.00
TOTAL GROUP	.41	.59	1.00

Based upon the definitions of independent and group learning provided to the teachers, it seems doubtful that teachers in the group treatment actually had their pupils spend 41 percent of their learning time on tasks that had been planned and discussed during an individual teacher-pupil conference. More likely, the independent learning carried out by these pupils was carried out without direct teacher supervision but assigned by the teacher to the group as a whole. According to the definitions stated earlier, this would be group learning. However, even using the teachers' data, the independent learning treatment did, on the average, devote at least twice as much of their learning time to independent learning activities as did the group treatment. Thus, a difference in the learning situations of the pupils in these treatments can be assumed to exist.

Data Sources

Examples of teacher use of the seven behaviors were obtained through use of 30-minute videotape recordings. During the middle five days of unit activity, the group learning teachers made a recording of their work with the entire class. The recording was made on a day when the teacher was introducing the study of one of the objectives in the unit. During the same five days, the teachers in the independent learning treatment made a recording of a planning session with an individual pupil. If, during the 30-minute period, the teacher completed the planning with one pupil, a second pupil met with the teacher to plan his activities until the time was exhausted. Scoring of teacher use of the behaviors was based upon the ratings of two independent observers. Scoring involved two levels of coding: (1) noting whether the behavior did or did not

occur; and (2) if the behavior did occur, scoring of the teacher's use of the behavior on a three-point qualitative rating scale. Reliability of rater scoring was .974 for the group treatment and .925 for the independent treatment.

Pupil performance in the mathematics unit was measured by pre and post tests of achievement designed to measure the specific learning objectives included in the unit. Reliability of the tests was established through a test-retest procedure. A reliability coefficient of .772 was obtained for the pretest. The coefficient for the posttest was .896.

Prior to the initiation of work on the measurement unit, information also was obtained regarding the pupils' general level of mathematics achievement and their general learning ability. The Iowa Tests of Basic Skills, Test A-1: Arithmetic Concepts and Test A-2: Arithmetic Problem Solving were used to measure mathematics achievement. The California Short Form Test of Mental Maturity, 1963 revision was used to measure general learning ability.

For the purposes of the study, pupil post-unit scores on the mathematics measurement test were used as the dependent variable. Mathematics achievement, general learning ability, and pre-unit measurement test scores served as independent variables.

Findings

Teacher mean total scores on the use of the seven teacher behaviors were found to differ significantly. Table III reports the results of the one-way analysis of variance.

TABLE III

Analysis of Variance
Total Teacher Behavior Scores

Source of Variance	df	Mean Squares	F-Ratio
Between Groups	3	347.286	11.523 $p<.001$
Within Groups	30	30.134	
TOTAL	33		

A posteriori Scheffé contrasts (Kirk, 1968) indicated that the trained independent teachers ($\overline{X}$ = 23.90) differed significantly ($p<.01$) from both the untrained independent ($\overline{X}$ = 14.22) and untrained group ($\overline{X}$ = 9.86) teachers. The trained group teachers ($\overline{X}$ = 21.56) differed significantly from the untrained group teachers but not from the teachers in the trained or untrained independent treatments. Knowledge of these differences aids in the interpretation of findings reported later in this paper.

The mean scores for the independent variables for the pupils in each treatment as defined by instructional approach and teacher training are presented in Table IV. One-way analyses variance supported the assumption of ~~new~~ no significant differences among treatments relative to achievement and intelligence (see Table V). However, the analysis for the pre-unit mean scores of mathematics measurement skills indicated that the groups differed significantly.

A two-way analysis of variance based upon a fixed effects model was used to test the hypothesis that there was no difference in the performance of pupils in the independent and group learning treatments.

TABLE IV

Treatment Mean Scores for Independent Variables

Treatment	N	Mathematics Achievement Mean	S.D.	General Learning Ability Mean	S.D.	Pretest Mean	S.D.
Trained Independent	94	4.94	1.13	113.03	19.36	134.34	32.16
Trained Group	70	5.38	1.27	114.17	12.25	143.66	44.51
Untrained Independent	85	5.08	1.19	111.99	11.28	141.19	32.88
Untrained Group	65	5.14	1.13	111.34	13.51	127.32	33.41

TABLE V

Analysis of Variance for Independent Variables

	Source of Variance	df	Mean Squares	F-Ratio	
Mathematics Achievement	Between Groups	3	2.666	1.01	p<.1278
	Within Groups	310	1.395		
General Learning Ability	Between Groups	3	108.258	.4967	p<.6849
	Within Groups	310	217.949		
Pretest	Between Groups	3	3778.190	2.967	p<.0324
	Within Groups	310	1274.697		

Analysis of covariance was used to adjust for differences in pretest means when comparing posttest results.

Table VI reports the observed means, adjusted means and standard deviations for pupil posttest scores. Table VII shows the results of the analysis of covariance with the covariate (pretest) eliminated.

Even when allowing a numerically large level of significance (α = .10 or .25) as recommended by Kirk (1968, p. 481) in order to avoid a Type II error resulting from the conservatism of the F-test if various assumptions of the analysis of covariance are not met, only the effect of approach to learning randomly assigned to classes is significant.

TABLE VI

Mean Scores for Posttest of Mathematics Measurement Skills

Trained Independent			Trained Group			Untrained Independent			Untrained Group		
Observed Mean	S.D.	Adjusted Mean	Observed Mean	S.D.	Adjusted Mean	Observed Mean	S.D.	Adjusted Mean	Observed Mean	S.D.	Adjusted Mean
163.81	38.33	165.60	183.64	50.72	178.00	168.98	35.07	165.30	170.48	37.53	177.90
n = 94			n = 70			n = 85			n = 65		

Observed Combined Mean (Trained) = 172.30
Adjusted Combined Mean (Trained) = 171.80

Observed Combined Mean (Untrained) = 169.90
Adjusted Combined Mean (Untrained) = 171.60

Observed Combined Mean (Independent) = 166.30
Adjusted Combined Mean (Independent) = 165.50

Observed Combined Mean (Group) = 177.30
Adjusted Combined Mean (Group) = 178.00

TABLE VII

Analysis of Covariance (Pretest as Covariate)
for Posttest Mathematics Measurement Skills

Source of Variance	df	Mean Squares	F-Ratio	
Training	1	1.677	.002	$\rho<.964$
Learning Approach	1	11973.646	14.43	$\rho<.0002$
Training X Approach	1	.4195	.005	$\rho<.982$
Error	309	829.761		

Inspection of the adjusted combined means for independent as compared with group approach to learning identified a difference of +12.50 in favor of the group approach. Using Scheffe's method to establish a .95 confidence interval, the difference between means for the approaches was found to have a lower limit of +1.38 and an upper limit of +23.62.

Given this finding, the difference in learning time reported earlier for the treatments assumes a practical significance. The added time devoted to unit activities by pupils in the group treatment may have influenced this outcome.

Measures of the relationship between teacher use of the specified behaviors and prediction of variance in pupil post-unit score were obtained through the use of step-wise multiple regression analysis. Within the ARIEL program used for this analysis, the equation for the first step selects the predictor variable that correlates highest with the

criterion, the next step selects the predictor variable that in concert with the first best predicts the criterion, and so forth.

The total amount of variance predictable from the predictor variables is represented by the squared multiple correlation between the predictors and the criterion variable. However, since the actual existing multiple correlation takes advantage of error variance, an unbiased coefficient is obtained. This unbiased coefficient is an estimate of the correlation between the predictors which might occur if the equation were applied to several samples from the same population. For purposes of this study, the equation producing the maximum unbiased multiple correlation coefficient was accepted as the best predictor of variance in the criterion variable.

Tables VIII and IX summarize the step-wise multiple regression analyses for posttest means for the independent and group treatment samples respectively. Since only one measure of teacher use of the specified behaviors was obtained in the independent treatment, rather than a measure of the interaction with each pupil, class means are used as the criterion variable. Also, each sub-level of the rating scale used to score teacher use of the behaviors is included as a unique predictor variable.

TABLE VIII

Step-Wise Multiple Regression Analysis
of Posttest Means Using Ten
Measures of Teacher Behavior
Independent Treatment

Step	Predictor Variable	Biased R	Unbiased R	F-Test*	
1	Specify How Learning Demonstrated	.3531	.2706	2.42	$\rho<.13$
2	Organize Learning Steps	.5531	.4682	3.53	$\rho<.05$
3	Describe Anticipated** Activity	.6127	.5005	3.00	$\rho<.06$
4	Specify Necessary Learning Steps	.6325	.4115	1.03	$\rho<.19$
6	Specify Verbal vs. Manipulative Activities	.6453	.3530	1.48	$\rho<.28$
7	Establish Deadlines	.6507	.2376	1.15	$\rho<.39$
8	Stress Acquisition of Knowledge vs. Higher Cognitive Skills	.6519	0.	.92	$\rho<.53$
9	Establish Checkpoints	.6524	0.	.4	$\rho<.66$
10	Identify Resources	.6524	0.	.59	$\rho<.78$

* Test of the significance of the multiple correlation

** Optimum equation

TABLE IX

Step-Wise Multiple Regression Analysis
of Posttest Means Using Ten
Measures of Teacher Behavior
Group Treatment

Step	Predictor Variable	Biased R	Unbiased R	F-Test*	
1	Describe Anticipated Activity	.4402	.3630	3.13	$\rho <$ .10
2	Establish Deadlines	.6219	.5334	3.78	$\rho <$ .05
3	Specify What to** Be Learned (Terms)	.7041	.5985	3.60	$\rho <$ .04
4	Specify How Learning Demonstrated	.7174	.5662	2.65	$\rho <$ .09
5	Stress Acquisition of Knowledge vs. Higher Cognitive Skills	.7217	.5047	1.95	$\rho <$ .18
6	Identify Resources	.7290	.4244	1.52	$\rho <$ .28
7	Establish Deadlines	.7390	.2977	1.19	$\rho <$ .41
8	Organize Learning Steps	.7404	0.	.91	$\rho <$ .56
9	Specify Verbal vs. Manipulative Activities	.7500	0.	.71	$\rho <$ .68
10	Specify Necessary Learning Steps	.7502	0.	.52	$\rho <$ .82

*Test of significance of the multiple correlation

**Optimum equation

It is interesting to note that the teacher behaviors contained in the optimum equations for the independent and group treatments differ. Only one behavior, describe anticipated activity, appears in both equations. To aid in the interpretation of the relation of these behaviors to the criterion variable, the coefficients for the optimum equations are presented in Table X.

TABLE X

Coefficients for Optimum Equation

Independent Treatment Behavior	Coefficient
Specify How Learning Demonstrated	14.744
Organize Learning Steps	-12.558
Describe Anticipated Activity	- 5.536
Group Treatment Behavior	**Coefficient**
Describe Anticipated Activity	-23.840
Establish Deadlines	19.958
Specify What to Be Learned	-16.156

The unbiased R^2 for the optimum equation in the independent treatment was .2505. In the group treatment it was .3581.

The appearance of the positive coefficient for specifying how learning will be demonstrated in the independent treatment is of interest. Inasmuch as a pupil working independently is required to function without the provision of continuous teacher-directed standards for acceptable

completed work, this finding should be expected. On the other hand, the predictive contribution of the behavior suggests the application of learning objectives theory is an important aspect of the independent learning situation.

In the interpretation of these findings several cautionary statements must be made. The suppression effects that occur in multiple correlations are not known for this study. Therefore, one variable may correlate highly with the criterion variable because a second predictor variable accounts for most of the variance of the first variable which is not common with the criterion variable. As noted by Wright and Nuthall (1970) the identification of the optimum equation for the prediction of post-unit scores is dependent upon the nature of the variation in the use of the behaviors that occurred among the teachers. A replication of this study might not produce the same results if teachers did not differ in the same way. Further, the reliability of the single sample of teacher behavior that was obtained is not known. And problems of interpretation arise because it was not possible to assign each pupil at random to a particular teacher as well as instructional treatment. However, since the general effect of these and other precautions such as a possible lack of normality score distributions for the use of the teacher behaviors is to make the test more conservative, it may be assumed that this study has underpredicted rather than overpredicted the relationship between the teacher behaviors and pupil learning outcomes.

Implications

Given the findings reported herein, the present study appears to have made two contributions to the body of research related to independent

learning and measurement of teacher behavior.

First, when the learning environment is controlled in terms of subject matter content and materials, and proportion of time devoted to independent vs. group learning, the group learning situation produces outcomes that are superior to those of the independent learning situation. Inasmuch as an effort was made to construct learning materials that were similar to those used in several individualized programs this finding may have some practical significance. Use of highly structured work sheets may be better accomplished in a group setting. However, this statement must be tempered by the knowledge that, in this study, the group treatment averaged about two hours more learning time.

Second, measurement of a specific set of teacher behaviors that define only a limited segment of the total teaching act (the joint teacher-pupil planning function) does aid in the prediction of variance in pupil learning outcomes. The estimates of variance obtained and the appearance of different behaviors in the optimum equations for the independent as compared with the group treatment suggest that measurement of precisely defined teacher behaviors may aid in definition of "effective teaching" for various instructional situations. Including or discarding carefully defined teaching behaviors as predictors of learning based upon a composite of the findings of numerous investigations offers an avenue for studying teaching at more than the general level of such characteristics as direct/indirect teaching style.

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